DOE/NIH Joint Workshop
Advancing Medical Care through Discovery in the Physical Sciences

Risk Reduction and Design of a 16-T MRI Magnet

July 12, 2021

GE Global Research
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Outline

- Magnet design considerations
  - Nb3Sn inner magnet, 9 T
  - NbTi outer magnet, 7T
- Nb3Sn conductor design
  - Evaluated 4 vendors
  - Working with Furukawa closely on the design
- Nb3Sn superconducting joint development
  - Unreacted wire joint
  - Reacted wire joint
- Electromagnetic design of a 16-T MRI magnet
  - Bore size
  - Homogeneity
  - Fringe field

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Magnet Design Considerations

NbTi MRI magnets up to 7 T mature in technology – product available

GE Global Research is building a brain 7T magnet with NIH funding

Inner Nb3Sn magnet produces 9 T in the 7 T background field

Total 16 T in the image volume

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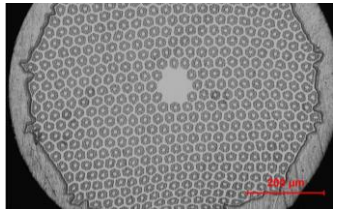
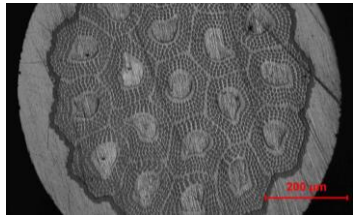
Nb3Sn Conductor Design

Evaluated Nb3Sn wires from 4 vendors

- Supercon, Luvata, HyperTech, and Furukawa

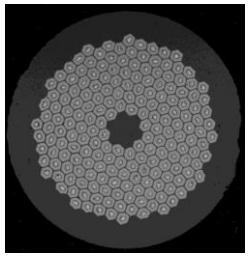


Supercon
Bronze Process

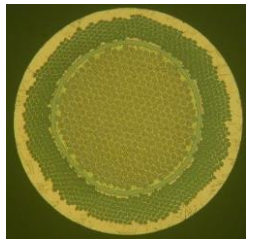


Supercon
Internal tin

Luvata
Internal tin



HyperTech
Rod restack



Furukawa
Nb/Cu reinforced

Furukawa Electric (FEI) design could take high stress under the 16 T field
Working with FEI closely to develop a new cross-section for our design

Select Furukawa rectangular Nb/Cu reinforced wire

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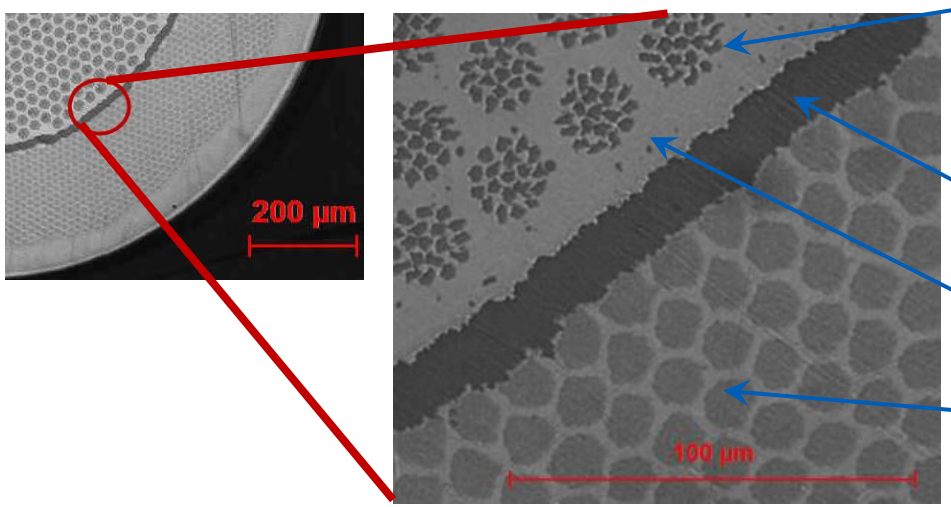
Nb3Sn Superconducting Joint Development

- Joint style investigated so far
  - Pigtail, disc, inline
- Connecting configuration
  - Etched wire filaments embedded in a powder matrix
  - Scarf surfaces with powders in between
  - Laser drilled holes filled with powders
- Removal of reaction barriers
  - Initial etching to remove sheathing and/or copper alloy shell (nitric acid)
  - Second etching to remove Ta reaction barrier (HF blend)
  - Optional 3rd etching to remove some internal matrix (nitric acid)

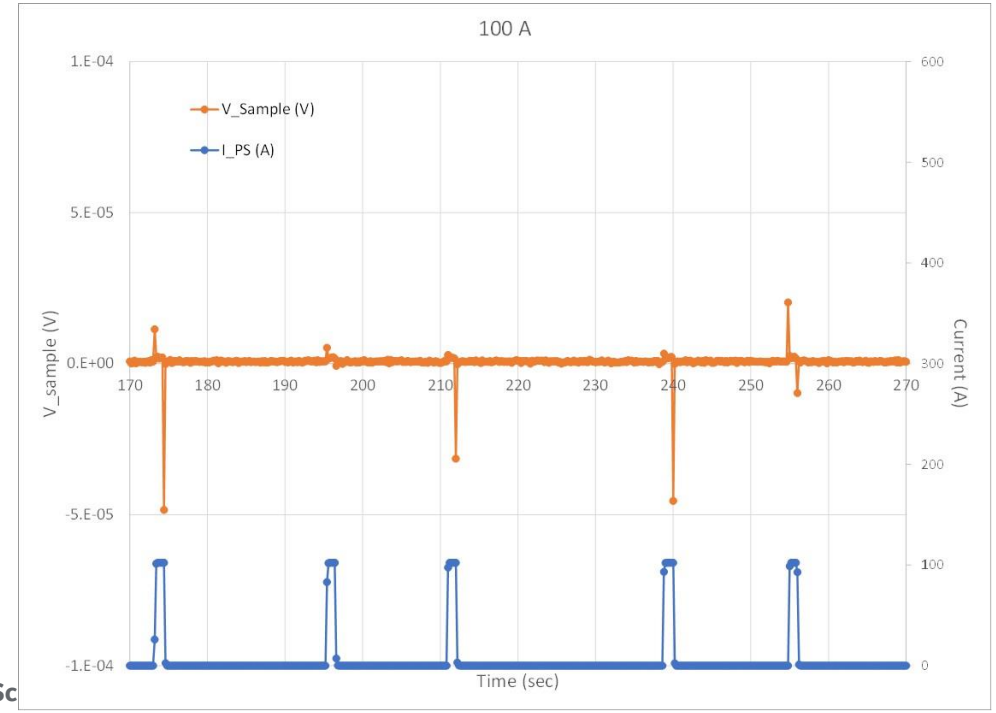
Examples of joints



- Unreacted wire joints
  - Superconducting up to 180A
  - Needs further improvement
- Reacted wire joints
  - Very limited success so far

Cylindrical pigtail joint

Bolted loaded disk joint



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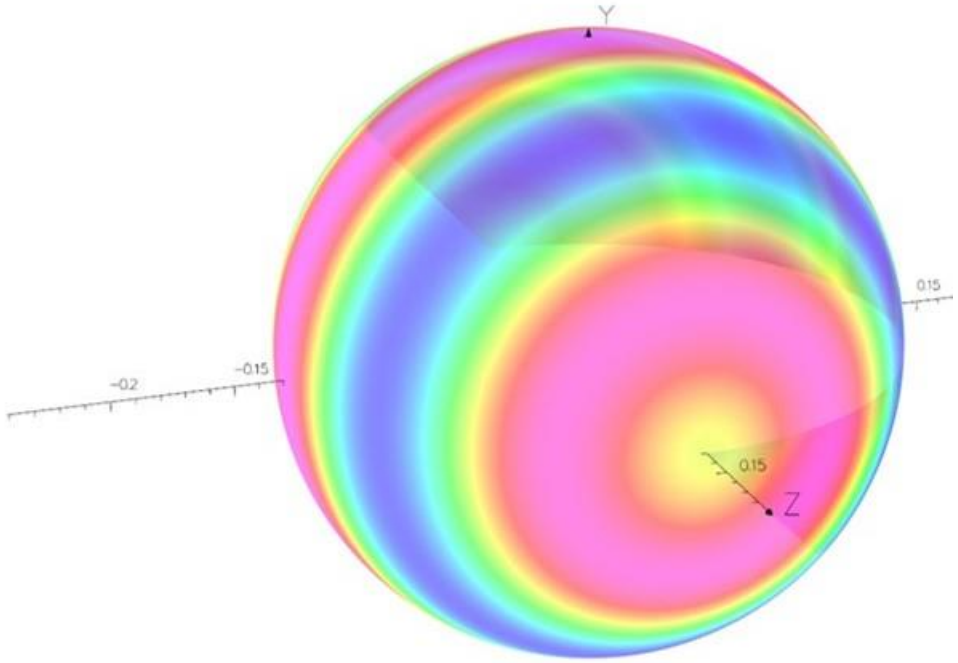
Electromagnetic Design of a 16-T MRI Magnet



Coil configuration of a 16-T MRI Magnet

Field plot at 26 dsv showing 0.6 ppm homogeneity

EM Design

Coil
1. Nb3Sn solenoid
2. NbTi solenoid
3. NbTi Large coil
4. NbTi Bucking coil

Main Parameters

Param	Unit	Value
Homo	ppm	0.60
DSV	cm	26
R_5G	m	8
Z_5G	m	10
Induct	H	3.71E+05
Energy	MJ	668
Lth_wire	km	7,732
Wt_wire	kg	98,348

Coil Dimension

coil	rc(cm)	zc (cm)	dr (cm)	dz (cm)	Bp (T)
1	56.595	85.658	39.990	171.316	16.05
2	95.279	18.407	18.558	36.813	6.86
3	100.202	111.922	28.060	126.520	7.91
4	177.611	125.553	15.440	106.273	6.29

coil	Prad (psi)	Pax (psi)	Frad (lb/in)	Fax (lb)
1	11,084	-4,632	747,597	-10,208,845
2	2,251	-787	32,621	-1,355,570
3	982	-11,460	48,897	-31,379,532
4	1,974	4,000	82,591	10,683,651

coil	Pr (MPa)	Pz (MPa)	Fr (kg/m)	Fz (kg)
1	76	-32	13,362,561	-4,634,816
2	16	-5	583,068	-615,429
3	7	-79	873,986	-14,246,308
4	14	28	1,476,233	4,850,378

coil	T (MN/m)	F (MN)	σ (Mpa)	ε (%)
1	43	74	108	0.12
2	15	5	80	0.06
3	7	9	24	0.02
4	24	26	157	0.12

Summary

- Carefully selected reinforced/strong Nb3Sn wire for the design
- Investigated a few configurations of Nb3Sn joints with some success
- Electromagnetic design showed magnet manufacturable

Thank you for your attention